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Ichthyological Note

Length–weight relationships of 20 fish species from the Sine Saloum estuary, Senegal, West Africa

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Running title: Length–weight relationships of fish from Sine Saloum estuary in Senegal

ABSTRACT

Length-weight relationships ($W=aL^b$) were estimated for 20 fish species collected during scientific fishing surveys conducted from April 1990 to October 2012 in the Sine Saloum estuary, Senegal, using purse seine, beach seine and fyke-net. The number of individuals varied from 10 (*Hemicaranx bicolor*) to 777 (*Carlarius latiscutatus*). Fish length ranged from 4.5 cm total length (*Sphoeroides marmoratus*) to 130.0 cm total length (*Sphyraena afra*). The values of parameter b in the LWR equations varied from 2.687 (*Hemicaranx bicolor*) to 3.334 (*Citharichthys stampflii*). The coefficient of determination (r^2) varied between 0.953 (*Sphoeroides marmoratus*) and 0.996 (*Sphyraena afra*). The length–weight relationship has never been studied before in Sine Saloum estuary for 13 fish species (*Carlarius parkii*, *Batrachoides liberiensis*, *Caranx senegallus*, *Hemicaranx bicolor*, *Trachinotus teraia*, *Elops senegalensis*, *Lutjanus goreensis*, *Citharichthys stampflii*, *Psettodes belcheri*, *Dagetichthys lusitanicus*, *Sphyraena afra*, *Sphyraena guachancho* and *Sphoeroides marmoratus*). This study provided LWRs that are not available in FishBase (Froese and Pauly, 2020) for *Carlarius latiscutatus*, *Carlarius parkii*, *Batrachoides liberiensis*, *Caranx senegallus*, *Hemicaranx bicolor*, *Cynoglossus senegalensis*, *Fontitrygon margarita*, *Plectorhinchus macrolepis*, *Pomadasys perotaei*, *Lutjanus goreensis*, *Citharichthys stampflii*, *Psettodes belcheri*, *Dagetichthys lusitanicus* and *Sphoeroides marmoratus*. It also provided size ranges that are not specified for LWRs in FishBase for *Ephippion guttifer*, *Elops senegalensis*, *Pseudotolithus senegalensis*, *Pseudotolithus senegallus* and *Sphyraena afra*. In addition, new maximum lengths are presented for *Plectorhinchus macrolepis* and *Citharichthys stampflii*. The parameters obtained from this study will be useful for proper fish population management in West African fisheries.

French title:

Relations taille-poids chez 20 espèces de poissons de l'estuaire du Sine Saloum au Sénégal, en Afrique de l'Ouest

RESUME.

Les relations taille-poids ($W=aL^b$) ont été estimées pour 20 espèces de poisson collectées au cours des missions de pêche scientifique effectuées d'avril 1990 à octobre 2012 dans l'estuaire du Sine Saloum, Sénégal, avec comme engin de pêche la senne tournante

couissante, la senne de plage et la nasse. Le nombre d'individus par espèce variait entre 10 (*Hemicaranx bicolor*) et 777 (*Carlarius latiscutatus*). La taille des poissons variait entre 4,5 cm de longueur totale (*Sphoeroides marmoratus*) et 130,0 cm de longueur totale (*Sphyraena afra*). Les valeurs du paramètre b de la relation taille-poids variaient de 2,687 (*Hemicaranx bicolor*) à 3,334 (*Citharichthys stampflii*). Le coefficient de détermination (r^2) variait entre 0,953 (*Sphoeroides marmoratus*) et 0,996 (*Sphyraena afra*). La relation taille-poids n'a jamais été étudiée auparavant pour 13 espèces de poissons (*Carlarius parkii*, *Batrachoides liberiensis*, *Caranx senegallus*, *Hemicaranx bicolor*, *Trachinotus teraia*, *Elops senegalensis*, *Lutjanus goreensis*, *Citharichthys stampflii*, *Psettodes belcheri*, *Dagetichthys lusitanicus*, *Sphyraena afra*, *Sphyraena guachancho* and *Sphoeroides marmoratus*) dans l'estuaire du Sine Saloum. Cette étude a fourni des informations sur les relations taille-poids qui n'existent pas encore dans FishBase (Froese and Pauly, 2020) pour les espèces *Carlarius latiscutatus*, *Carlarius parkii*, *Batrachoides liberiensis*, *Caranx senegallus*, *Hemicaranx bicolor*, *Cynoglossus senegalensis*, *Fontitrygon margarita*, *Plectorhinchus macrolepis*, *Pomadasys perotaei*, *Lutjanus goreensis*, *Citharichthys stampflii*, *Psettodes belcheri*, *Dagetichthys lusitanicus* and *Sphoeroides marmoratus*. Elle a aussi fourni des gammes de taille qui ne sont pas spécifiées dans FishBase pour la relation taille-poids de 5 espèces (*Ephippion guttifer*, *Elops senegalensis*, *Pseudotolithus senegalensis*, *Pseudotolithus senegallus* and *Sphyraena afra*). En outre, de nouvelles tailles maximales sont présentées pour *Plectorhinchus macrolepis* et *Citharichthys stampflii*. Les paramètres obtenus à partir de cette étude seront utiles pour une bonne gestion des populations de poissons dans les pêcheries d'Afrique de l'Ouest.

Keywords: Length–weight relationship, Fish species, Saloum estuary, Senegal.

Introduction

The relationship between length and weight of individuals in a fish population, with several other essential parameters is a basic tool for fishery scientists, managers and biologists to assess the natural population dynamics (Le Cren, 1951; Froese, 2006). Fish length-weight relationships are useful in the estimation of fish population size (Dulčić and Kraljević, 1996; Froese, 2006; Giarrizzo et al., 2015), of biomass from length observations (Petrakis and Stergiou, 1995; Gonçalves et al., 1997) and to assess stocks (Hampton, 2000; Fromentin and

Fonteneau, 2001). Studies on length-weight relationships provide information about growth patterns (Okgerman, 2005), fisheries biology and population dynamics (Sivashanthini, 2008).

In this study, we assessed length-weight relationships for 20 species from the Sine Saloum estuary. This work complements those of Ecoutin and Albaret (2003) and Ndiaye et al. (2015) on some species in the Sine Saloum estuary. In addition, we have drawn up a table of LWRs of certain species whose LWRs have already been studied in the Sine Saloum estuary in order to observe differences, bearing in mind that the sampling methodologies are not the same compared to that of Ndiaye et al. (2015).

Materials and Methods

The Sine Saloum estuary is located 100 km south of Dakar, in Senegal, between 13°55' and 14°10' North and 16°03' and 16°50' West. The Sine Saloum is an inverse estuary characterized by an increase in salinity from downstream to upstream in all seasons. The system comprises three main branches: from north to south, the Saloum, the Diomboss and the Bandiala, connected to each other by a vast network of small mangrove creeks locally named "bolong". Mangrove forests cover almost the entire southern portion of the system and progressively diminish in the North (Diouf, 1996; Simier et al., 2004). Data were collected during scientific fishing surveys. The whole Sine Saloum estuary was sampled first from April 1990 to May 1993 (Diouf, 1996), with occasional samplings in 1994 and 1997, and then from 2002 to 2003 (Ecoutin et al., 2010), with additional samplings from 2004 to 2007. The Bamboung bolong, a small tributary of the Diomboss, which has become a Marine Protected Area in 2004, was subject to a biological monitoring from 2003 to 2012 and the Sangako bolong, not far from the Bamboung Marine Protected Area but open to fishing, was also sampled for comparison from 2008 to 2012 (Ecoutin et al., 2014; Sadio et al., 2015). Most sampling was carried out during the three main hydro-climatic seasons of the region, *i.e.* in March (end of the cool dry season), May-June (end of the hot dry season) and October (end of the wet season). The fish were caught using a purse seine (length 250 m, height 20 m, 14 mm mesh size; see Simier et al., 2004), a beach seine (180 m length, 9 m height and 25 mm mesh net; see Diouf, 1996) and fyke-nets (diameter, 40 cm; length, 3 m; with two 1.5-m wings adjacent to the opening; see Gning et al., 2008). Fish were identified to the species level and measured to the nearest mm (fork length for fish with a forked caudal fin with crescent or indented form; total length for species with a rounded caudal fin with a pointed or truncated form; disc width for rays) and weighed to the nearest g. All data are available in

PPEAO database (Simier et al., 2019). Linear regressions of $\log(W)$ vs. $\log(L)$, where W is total weight in g, L is total or fork length or disc width in cm were calculated to obtain the length-weight relationship of the form $W = aL^b$ (Froese, 2006) where $\log(a)$ is the intercept and b is the slope of the regression. Length and weight data were first plotted to identify outliers, the most extreme of which were finally excluded from the analyses. Samples with $n < 10$ were excluded from the regression analyses.

Results

Twenty fish species belonging to 14 families were considered in this study, making up 3293 individuals measured in the whole Sine Saloum estuary. Sample size, length and weight ranges, parameters of the LWR equations with 95% confidence limits and values of the determination coefficient r^2 were computed for the 20 species and reported in Table 1. The sample size for a given species, varied from 10 (*Hemicaranx bicolor*) to 777 (*Carlarius latiscutatus*) individuals. Fish size ranged from 4.5 cm total length (*Sphoeroides marmoratus*) to 130 cm fork length (*Sphyraena afra*). The values of parameter b in the LWR equations varied from 2.687 (*Hemicaranx bicolor*) to 3.334 (*Citharichthys stampflii*). Linear regressions were significant for all species ($p < 0.001$) and provided suitable adjustments: the coefficient of determination (r^2) varied between 0.953 (*Sphoeroides marmoratus*, $n=58$) and 0.996 (*Sphyraena afra*, $n=68$). For 7 of the 20 species, LWRs have already been published for the Sine Saloum estuary (Table 2) but with a smaller number of individuals (*Fontitrygon margarita*, *Plectorhinchus macrolepis*) or with a smaller size range (*Pseudotolithus senegalensis*) or with both a smaller number of individuals and a smaller size range (*Carlarius latiscutatus*, *Cynoglossus senegalensis*, *Pomadasys perotaei*, *Ephippion guttifer*). For the remaining 13 fish species, no information on LWRs was yet available in Senegal.

Discussion

The use of fishing gears with small mesh sizes (14 mm) allowed the sampling of a large range of sizes for most species from juveniles to adults. The Sine Saloum estuary is known to be a nursery area frequented by juvenile fish (Vidy, 2000) and a reproduction area (Diouf, 1996, Panfili et al., 2004a, b; Panfili et al., 2006; Albaret et al., 2005; Diop et al., 2017), what reflects the large size range of several species sampled.

This study provided LWRs that are not available in FishBase (Froese and Pauly, 2020) for *Carlarius latiscutatus*, *Carlarius parkii*, *Batrachoides liberiensis*, *Caranx senegallus*, *Hemicaranx bicolor*, *Cynoglossus senegalensis*, *Fontitrygon margarita*, *Plectorhinchus macrolepis*, *Pomadasys perotaei*, *Lutjanus goreensis*, *Citharichthys stampflii*, *Psettodes belcheri*, *Dagetichthys lusitanicus* and *Sphoeroides marmoratus*. It also provided size ranges that are not specified for LWRs in FishBase for *Ephippion guttifer*, *Elops senegalensis*, *Pseudotolithus senegalensis*, *Pseudotolithus senegallus* and *Sphyraena afra*. In addition, new maximum total lengths are presented for *Plectorhinchus macrolepis* (53.8 cm vs. 45.0 cm) and *Citharichthys stampflii* (17.5 cm vs. 16.0 cm). For the 7 species already studied in the Sine Saloum estuary, the differences can be due to the difference in size range or number of individuals in the case of the species studied by Ecoutin et Albaret (2003) and by differences in sampling method and equipment, season and area for the species studied by Ndiaye et al. (2015).

For all of the studied species in this study, the b values were generally in agreement with previous results by Froese (2006) i.e. b value comprised between 2.5 and 3.5. Also, it is well known that the b value represents the body form, and is directly related to the weight affected by ecological factors such as temperature, food supply, spawning conditions and other factors (Ricker, 1973). Regression results suggest that the data from this study and the results presented here are reliable and can enriched Senegalese length-weight relationships in FishBase (Froese and Pauly, 2020). They will be a useful tool to increase the ecological knowledge of these species in Sine Saloum estuary.

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Table 1. Length–weight relationship (LWR) of 20 fish species from the Sine Saloum estuary in Senegal, from April 1990 to October 2012. Species: a, fork length; b, Total length; c, Disc width. Abbreviations: n, sample size; Max, maximum; Min, minimum; a and b, parameters of LWR; CL, confidence limits; r^2 , coefficient of determination.

Family	Species	n	Length (cm)	Weight (g)	Relationship parameters		
			Min-Max	Min-Max	a (95%CL)	b (95%CL)	r^2
Ariidae	<i>Carlarius latiscutatus</i> ^a (Günther, 1864)	777	15.5-61.4	48-4100	0.006 (0.005-0.006)	3.2367 (3.2082-3.2652)	0.985
	<i>Carlarius parkii</i> ^a (Günther, 1864)	460	14.8-52.5	39-2225	0.009 (0.008-0.010)	3.1236 (3.0941-3.1531)	0.990
Batrachoididae	<i>Batrachoides liberiensis</i> ^b (Steindachner, 1867)	212	5.0-32.8	2-630	0.014 (0.012-0.017)	3.0541 (2.9965-3.1117)	0.981
Carangidae	<i>Caranx senegallus</i> ^a Cuvier, 1833	43	8.6-51.5	9-2035	0.013 (0.011-0.017)	3.0885 (3.0048-3.1722)	0.993
	<i>Hemicaranx bicolor</i> ^a (Günther, 1860)	10	6.2-12.6	5-34	0.036 (0.021-0.060)	2.6871 (2.4417-2.9324)	0.988
	<i>Trachinotus teraia</i> ^a Cuvier, 1832	140	15.2-67.0	80-8250	0.015 (0.012-0.018)	3.1302 (3.0754-3.185)	0.989
Cynoglossidae	<i>Cynoglossus senegalensis</i> ^b (Kaup, 1858)	184	11.6-61.0	6-677	0.005 (0.004-0.006)	2.9209 (2.8778-2.9640)	0.990
Dasyatidae	<i>Fontitrygon margarita</i> ^c (Günther, 1870)	71	10.0-58.5	37-9200	0.034 (0.026-0.044)	3.0731 (2.9875-3.1588)	0.987
Elopidae	<i>Elops senegalensis</i> ^a Regan, 1909	75	17.4-55.3	45-1545	0.010 (0.008-0.013)	2.9444 (2.8673-3.0214)	0.988
Haemulidae	<i>Plectorhinchus macrolepis</i> ^b (Boulenger, 1899)	110	14.9-53.8	56-2834	0.014 (0.012-0.017)	3.0920 (3.0320-3.15210)	0.990
	<i>Pomadasys perotaei</i> ^a (Cuvier, 1830)	696	8.0-34.5	8-554	0.017 (0.016-0.018)	2.9762 (2.9574-2.9949)	0.993
Lutjanidae	<i>Lutjanus goreensis</i> ^b (Valenciennes, 1830)	112	23.8-59.0	213-3460	0.013 (0.010-0.016)	3.0402 (2.9742-3.1062)	0.987
Paralichthyidae	<i>Citharichthys stampflii</i> ^b (Steindachner, 1894)	68	5.3-17.5	1-58	0.004 (0.003-0.005)	3.3341 (3.1933-3.4749)	0.971
Psettodidae	<i>Psettodes belcheri</i> ^b Bennett, 1831	13	15.0-44.4	36-880	0.009 (0.004-0.020)	3.0639 (2.8164-3.3114)	0.985
Sciaenidae	<i>Pseudotolithus senegalensis</i> ^b (Valenciennes, 1833)	32	11.5-38.4	11-441	0.006 (0.004-0.007)	3.1000 (3.0100-3.1900)	0.994
Soleidae	<i>Dagetichthys lusitanicus</i> ^b (de Brito Capello, 1868)	14	10.0-39.0	5-468	0.003 (0.002-0.004)	3.2626 (3.119-3.4063)	0.995
Sphyraenidae	<i>Sphyraena afra</i> ^a Peters, 1844	68	18.0-130.0	31-11500	0.006 (0.005-0.007)	2.9882 (2.9442-3.0322)	0.996
	<i>Sphyraena guachancho</i> ^a Cuvier, 1829	26	16.1-33.0	25-233	0.009 (0.006-0.014)	2.8756 (2.7537-2.9974)	0.990
Tetraodontidae	<i>Ephippion guttifer</i> ^b (Bennett, 1831)	124	8.4-60.2	15-4150	0.020 (0.017-0.023)	2.9911 (2.9488-3.0334)	0.994
	<i>Sphoeroides marmoratus</i> ^b (Lowe, 1838)	58	4.5-12.2	2-31	0.024 (0.016-0.031)	2.8146 (2.6465-2.9828)	0.953

Table 2. Synthesis of studies on Length–weight relationship (LWR) of 7 fish species from the Sine Saloum estuary in Senegal studied before (Ecoutin and Albaret, 2003; Ndiaye et al., 2015). Abbreviations: n, sample size; Max, maximum; Min, minimum; a and b, parameters of LWR; TL, total length; FL, fork length; SL, standard length; DW, disc width; CL, confidence limits if available; r^2 , coefficient of determination.

Species	n	Length	Weight (g)	Relationship parameters			Author	Ecosystem
		Min – Max	Min – Max	a (95% CL)	b (95% CL)	r ²		
Ariidae								
<i>Carlarius latiscutatus</i> (Günther, 1864)	58	160 – 523 (FL) (mm)		1.11. 10 ⁻⁵	3.028	0.964	Ecoutin and Albaret, 2003	Saloum (Senegal)
	130	20.5 – 28.4 (TL) (cm)	52.4 – 72.6	0.025	2.540	0.920	Ndiaye et al., 2015	Saloum (Senegal)
Cynoglossidae								
<i>Cynoglossus senegalensis</i> (Kaup, 1858)	34	111 – 540 (TL) (mm)		3.91. 10 ⁻⁵	2.625	0.882	Ecoutin and Albaret, 2003	Saloum (Senegal)
Dasyatidae								
<i>Fontitrygon margarita</i> (Günther, 1870)	27	100 – 585(DW) (mm)		16.83. 10-5	2.748	0.924	Ecoutin and Albaret, 2003	Saloum (Senegal)
Haemulidae								
<i>Plectorhinchus macrolepis</i> (Boulenger, 1899)	23	149 – 670 (TL) (mm)		4.29. 10-5	2.855	0.978	Ecoutin and Albaret, 2003	Saloum (Senegal)
	16	16.0 – 31.5 (TL) (cm)	42.5 – 295.4	0.030	2.830	0.960	Ndiaye et al., 2015	Saloum (Senegal)
<i>Pomadasys perotaei</i> (Cuvier, 1830)	178	100 – 281 (FL) (mm)		0.001	2.677	0.966	Ecoutin and Albaret, 2003	Saloum (Senegal)
	57	15.1 – 32.2 (TL) (cm)	37.8 – 286.2	0.032	2.750	0.970	Ndiaye et al., 2015	Saloum (Senegal)
Sciaenidae								
<i>Pseudotolithus senegalensis</i> (Valenciennes, 1833)	78	18.5 – 28.0 (TL) (cm)	52.1 – 166.2	0.015	2.79	0.980	Ndiaye et al., 2015	Saloum (Senegal)
Tetraodontidae								
<i>Ephippion guttifer</i> (Bennett, 1831)	58	13.5 – 30.5 (TL) (cm)	51.5 – 578.3	0.025	2.92	0.990	Ndiaye et al., 2015	Saloum (Senegal)